Green Ammonia

REFUEL Kickoff Meeting, August 17, Denver

Elfriede Simon, CT REE STS

Decarbonization of global economy by 2100 and fundamental changes in worldwide energy market already today

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Politics force worldwide decarbonization

- **G7 summit, 2015:**
  - Decarbonization of the global economy by 2100
  - Greenhouse gas emissions reductions of 40% to 70% by 2050 (baseline: 2010)
- **COP21, 2015:**
  - 195 countries adopt the first universal climate agreement
  - Keep a global temperature rise this century well below 2°C
- **COP22, 2016:**
  - Establish a rulebook for monitoring greenhouse gas emissions until 2018
  - Underline the pre-agreed "$100bn a year by 2020" goal
  - GER, USA, CAN and MEX published strategies for radically cutting their greenhouse gas emissions

World energy market 2016

– Renewable power	**921 GW, 2015: 785 GW[1]**
– PV market	**303 GW**
– Wind market	**487 GW**
– Global investment in REN	**$241.6 billion[2]**
– REN of total electricity	**24.5%, 2015: 23,7%**
– Germany:	
– Renewable power	**105 GW, 2000: 11.4 GW → increase by factor 9**
– REN / gross elect. consump.	**32.6%**

- In 2016, worldwide several record-low bids for PV in a row:
  Mai: 2.99 cent$/kWh for 800 MW (Dubai)
  Aug: 2.91 cent$/kWh (Chile)
  Sep: 2.40 cent$/kWh for 350 MW (Abu Dhabi)

2016: "More for less" – record year for global renewables investment, lowest solar prices ever
Decarbonization offers high business potential for Siemens, both for traditional and disruptive technologies

Sources: [1]without hydro, REN21, [2]without hydro, Frankfurt School FS-UNEP Collaborating Centre, [3]The International Renewable Energy Agency
General sources: BMWi, Fraunhofer-Institut für Solare Energiesysteme, Bundesverband der Energie- und Wasserwirtschaft, https://www.g7germany.de/, http://www.consilium.europa.eu/en/home/, www.cop21.gouv.fr, www.cop22-morocco.com

The decarbonization will transform the entire energy value chain – with strong growth rates and a complete electr(on)ification

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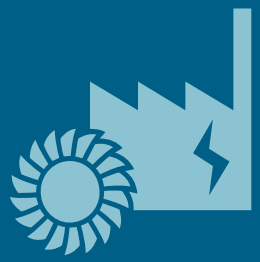
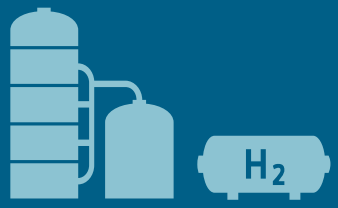
Strong demand for highly efficient power plants, flexibility and lower emissions



Massive trend towards distributed generation and renewables

Digitalization as new driver for technology progress and new business models

Energy storage innovation shaping the future power industry landscape



Electrification of applications, especially in the transport sector

Storage- & Power-to-X-Technologies are required to balance consumption vs. renewable generation and support sector coupling

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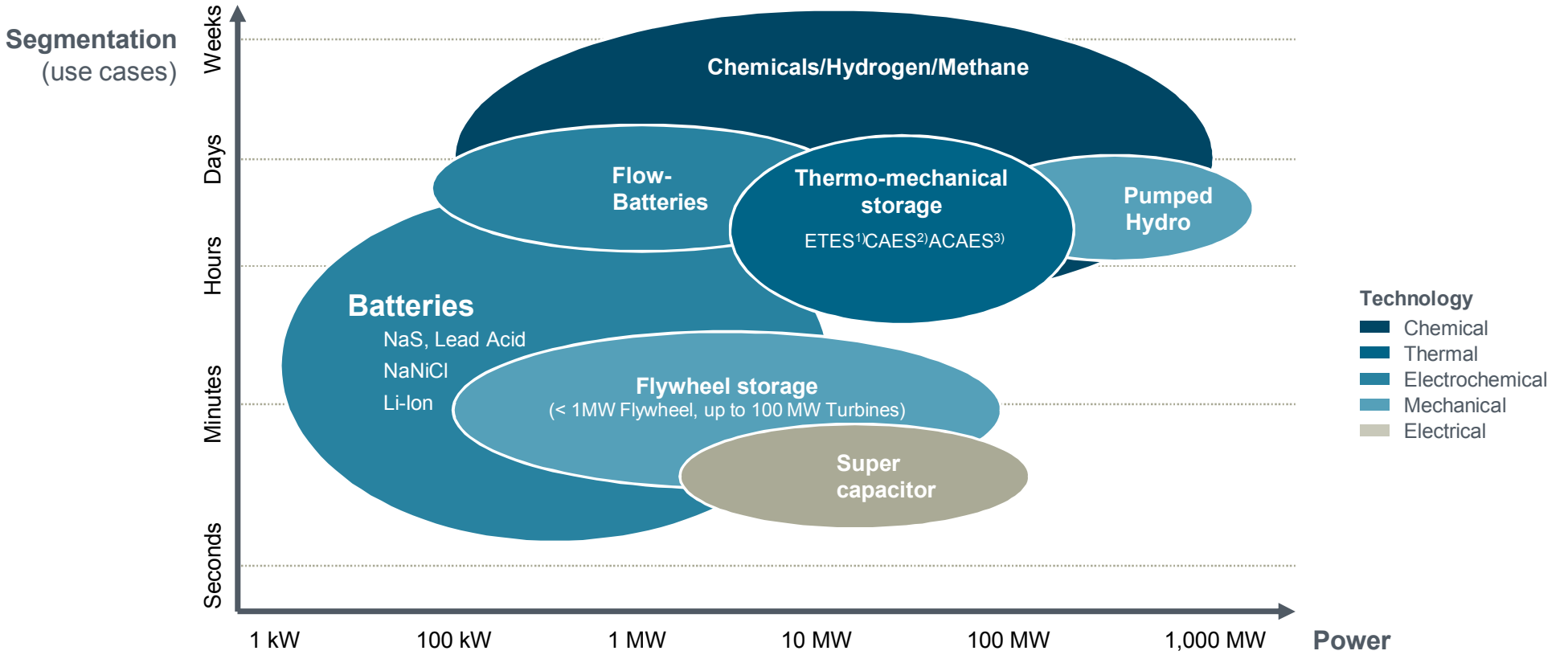

1) Electro-Thermal Energy Storage
2) Compressed Air Energy Storage
3) Adiabatic Compressed Air Energy Storage

Ammonia provides a practical, carbon-free hydrogen carrier, allowing cost-effective storage and transportation of green energy

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N_2 from air

+

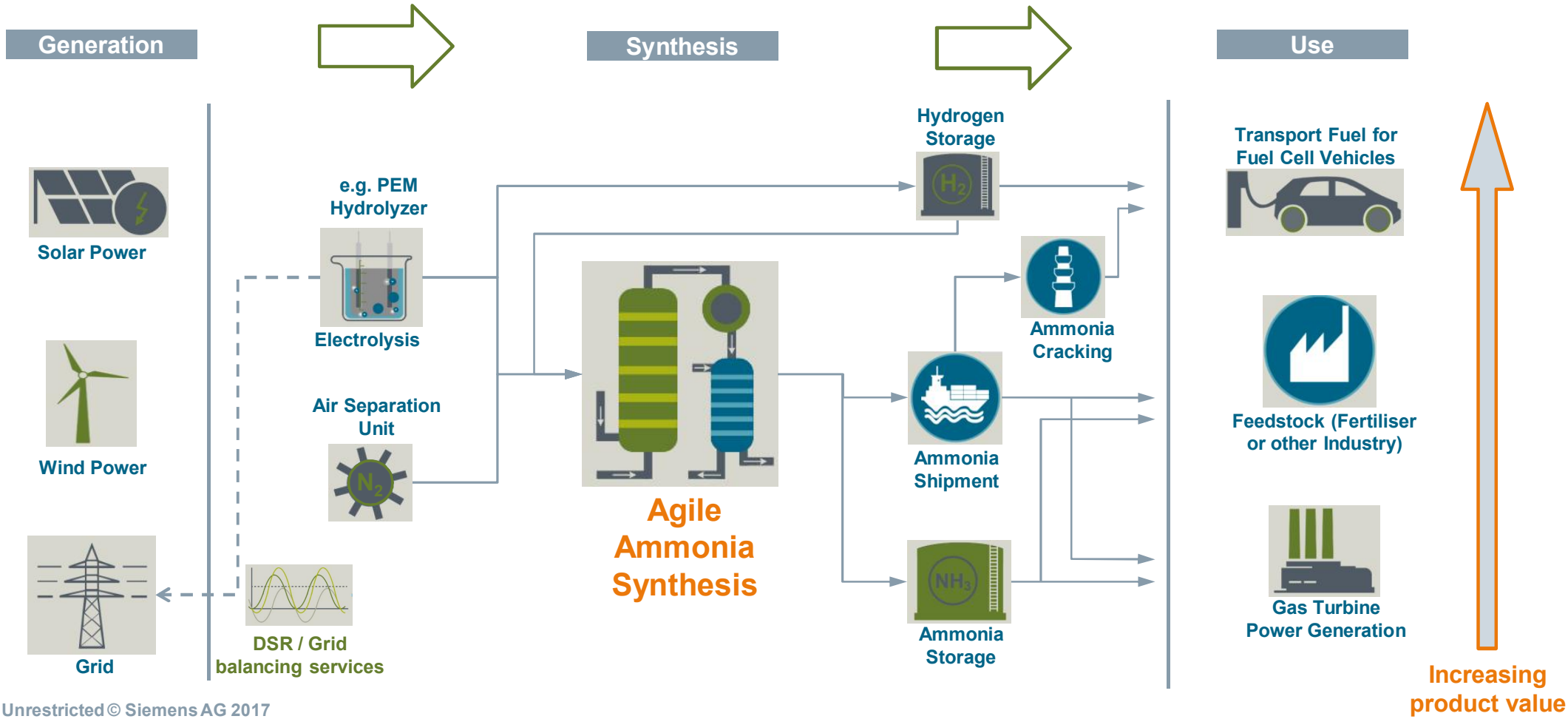
Water

+

Renewable Electricity

Electrochemically produced green ammonia

Several potential markets exist for Green Ammonia: it is a carbon-free flexible asset



Siemens SILYZER: PEM electrolysis projects for H_2 production

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Country	Project	Capacity	Product offering
Germany	Air Liquide (Hydrogen Refueling Station Krefeld)	300 kW	Container solution
Switzerland	Paul-Scherrer-Institut (ESI)	300 kW	Container solution
Germany	Karlsruhe Institut of Technology (Energy Lab 2.0)	300 kW	Container solution
Germany	Municipality of Mainz (Energiepark)	3,75 MW / 6 MW (peak)	Pilot SILYZER 200
Germany	Municipality of Haßfurt & Greenpeace Energy (WindGas Haßfurt)	1,25 MW	SILYZER 200
Germany	Refinery in northern part of Germany	5 MW	SILYZER 200
Australia	ACT (HRS near wind farm)	1,25 MW	SILYZER 200
Austria	Steel industry	6 MW	Pilot SILYZER 300

Sources: Siemens AG, VoestAlpine

Siemens is building a Green Ammonia energy storage demonstration system in the UK

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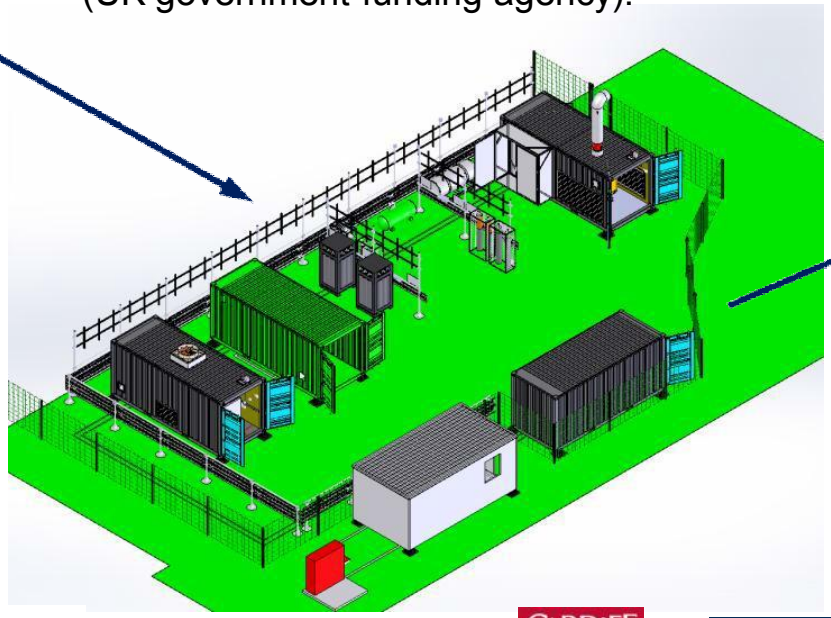
- Being built at Rutherford Appleton Laboratory, near Oxford, UK.
- Project 50% supported by Innovate UK (UK government funding agency).



- Evaluation of all-electric synthesis and energy storage demonstration system by June 2018.

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Green Ammonia Demonstrator demonstrate the complete cycle of renewable power, storage as NH_3, and re-electrification

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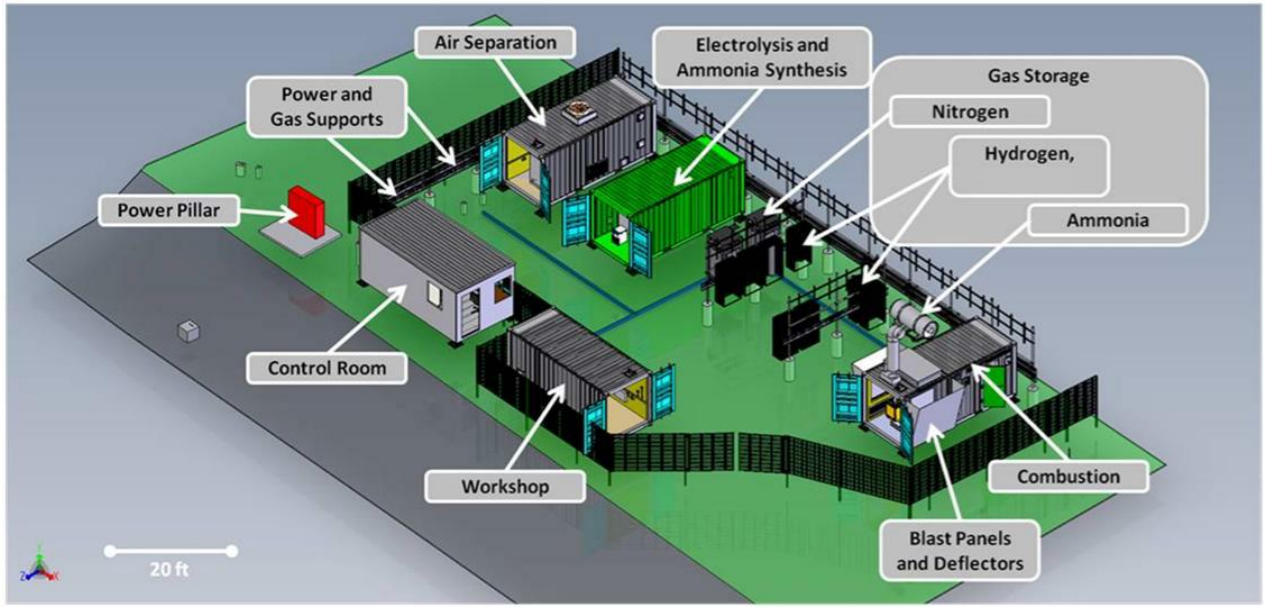

- Proof-of-principle for Agile H-B, and ammonia energy storage.
- Development platform for future demonstration: cracker, refuelling station; electrochemical ammonia synthesis; plant optimisation etc.

Development pathway for Green Ammonia: deploying mature technology today, developing technology improvements for the future

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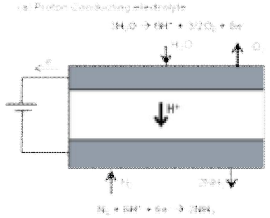
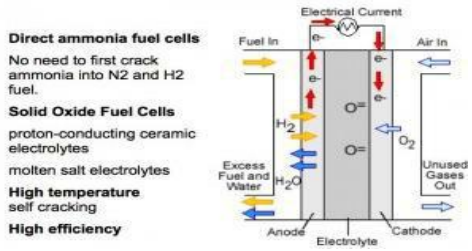
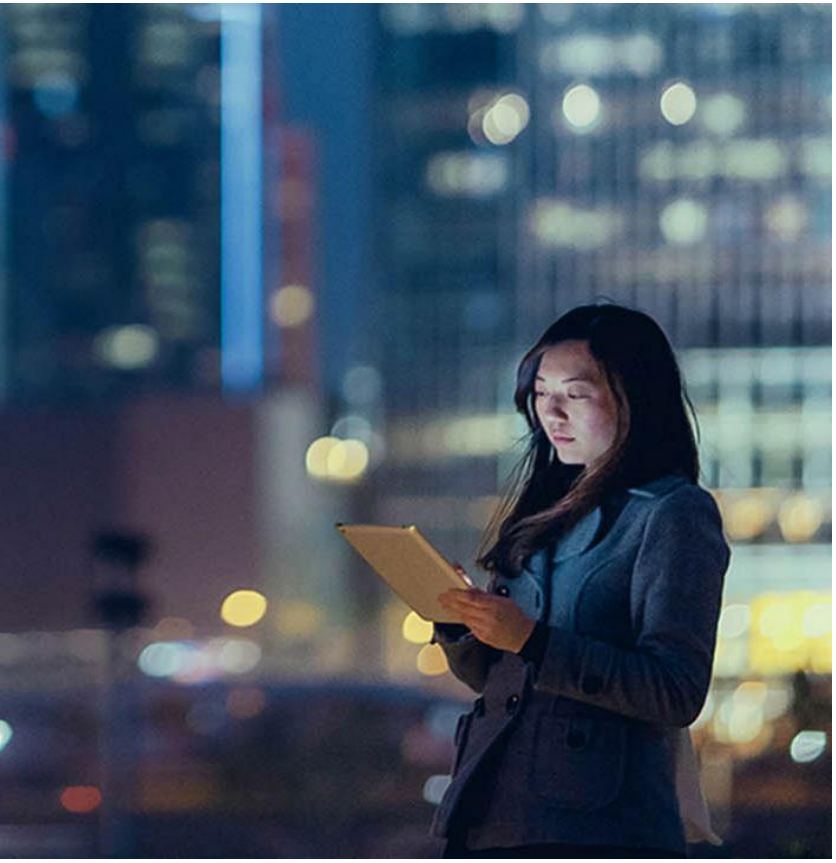
2017	2023	2030
Centralised Haber-Bosch synthesis	All electric Haber-Bosch dynamic, distributed	Large scale, distributed electrochemical synthesis
		
		
NH3 internal combustion engine	NH3 Gas Turbines	NH3 Fuel Cell ?

Contact page



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